How to design technical and organizational innovations to promote sustainable development in catchments with intensive use of pesticides

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Introduction

The sustainable development of agriculture in regions where perennial crops such as grapevine in south France and banana in the French West Indies dominate is questioned in relation to their high use of pesticides. The resulting degradation of the environment generates damages for various activities including agriculture. The cost of adopting alternative crop protection strategies and/or restoring water quality is high. The consequences on human health and environment generates conflicts with other stakeholders with feedback consequences on agriculture in terms of policy (regulations), market and social recognition. The observed low diffusion of low-input cropping systems results from technical, economic and organizational limitations at several scales, from field and farm to catchment and region. Then any proposal of alternative technologies should be embodied in sets of consistent innovations of different natures and at different scales.

In terms of research methodology, the challenge is to design novel agricultural systems and carry out *ex-ante* their assessment in a way that connects various scales and balances all dimensions of sustainability (Van Ittersum *et al.*, 2008). Various methods of integrated assessment have been proposed; they are all based on systems analysis, they mobilize in a concerted way several disciplines and use models as a mean to explore the effectiveness of various scenarios (Parker *et al.*, 2002).

In the present project, skills in human (economy, geography, sociology) and biophysical (agronomy, hydrology, engineering) sciences were gathered to (i) design innovative farming systems that would reduce the use and diffusion of pesticides, (ii) evaluate their ecological effectiveness and likelihood of adoption by farmers and (iii) identify the organizations and regulations that would favour sustainable development in the studied catchments.

Methods

A generic framework was adopted to organize the various scientific disciplines and approaches (Figure 1). The focus was more on the integration and consistency of these approaches than on the formal connection of a set of models differing in various ways: static/dynamic, mechanistic/empirical, biophysical/decisional, field/farm/catchment.

The influence of the institutional context was examined in two ways. First, a typology of mechanisms of incitation or repression was built and their potential impact on farming systems assessed with linear programming. Second, the role of networks of information among farmers in relation with the diffusion of innovations was studied and modelled with Multi-Agent Systems.

The design of innovative farming systems was made according to two approaches. In the grapevine catchment, surveys were carried out to analyse the diversity of farmers' strategies of weeding, soil management and crop protection. Some of these existing strategies were identified as innovative. In the banana catchment, it was considered that an input of novel techniques had to be introduced. To this end, a process of prototyping was engaged with experts (agronomists, geneticists, nematologists) after the typology of farming systems. It produced innovative cropping systems and bio-economic modelling was used to select those potentially fitting with the various types of farming systems.

The economic and environmental performances of the innovative farming systems were

assessed with biophysical models and/or indicators. This assessment focused on farm scale in the case of banana (the innovation resulting from the adoption of novel cropping systems by farmers) and on catchment scale in the case of grapevine (the innovation resulting from new distributions of performing types of farming systems within the population of farms).
At last the adoptability of the most effective farming systems was evaluated with new surveys and the conditions of adoption were identified with an econometric model.

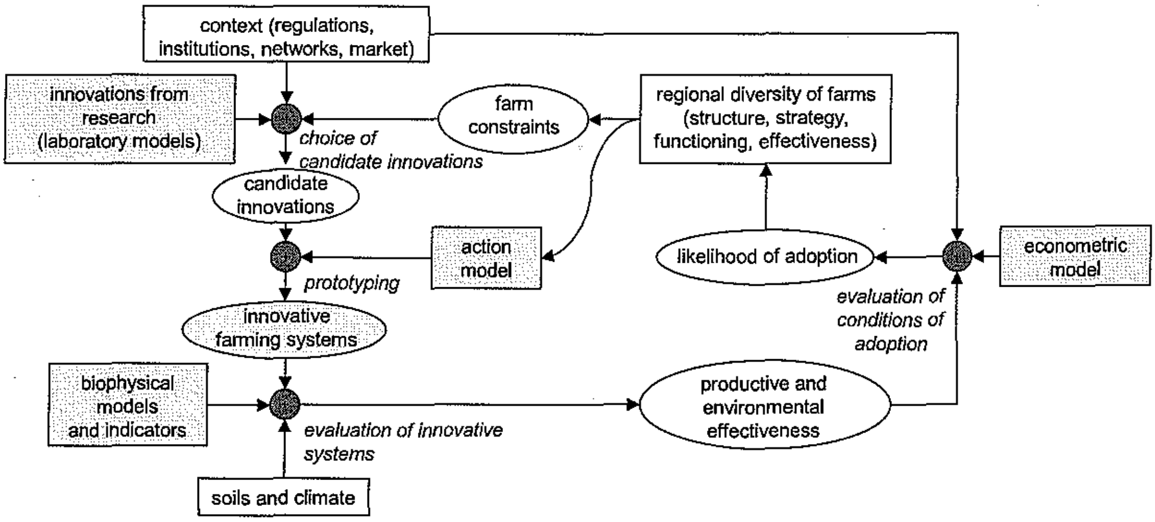

Figure 1. Scientific framework for the integrated assessment of innovative farming systems (grey rectangles are models, white rectangles, the real world, and ovals outputs).

Results and discussion

Government and farmers' institutions recently introduced new instruments and, in some cases, their theoretical effectiveness could be assessed. The fluxes of information within farmers' networks appeared to limit the diffusion of innovation. Yet the process of design of innovative farming systems differed among grapevine and banana catchments, this social context was considered as a forcing variable in both cases. The economic and ecological crisis was more severe in banana catchments, which justified the interest for radical technical innovations and for their thorough assessment at farm scale.

A set of assessment tools were produced, from field to farm and catchment, including breakthroughs such as the coupled simulation of the dynamics of crop and nematode development in banana fields, or the coupled simulation of cultivation techniques and resulting surface transfer of water and pesticide distributed within a grapevine catchment.
Attention was paid to the likelihood of adoption of innovative systems by farmers, in relation to the economy and organization of their farm and to the innovation and policy attributes. Combined with the evaluation of crop production and externalities, it provided a framework for an appraisal of the contribution to sustainable development of existing and alternative farming systems. The coupling of various scales and criteria of evaluation should facilitate the analysis of the consequences of specific policies designed to promote novel farming systems. In this perspective, the interaction with stakeholders, including policymakers, will have to be more formalized.

References

Parker, P., *et al.*, 2002. Environmental Modelling & Software 17: 209-217.
Van Ittersum, M.K., *et al.*, 2008. Agricultural Systems 96: 150-165.